Economic, Technical and Political Aspects of LNG Carriers in Comparison with NG Pipelines

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This paper is based on the invited paper presented by the writer at the "United Nations Symposium *on Natural Gas Transport and Utilization in Northeast Asia*" held in Beijing, China, 4-6 December, 2000. Natural gas has been attracting public attention recently. Here, the discussion is to be concentrated on the problem of its transportation in the Northeast Asia. Comparison between the LNG carrier and the NG pipeline is geopolitically made from an economic and technical viewpoint.

1. Merits and demerits of natural gas in comparison with the other energy resources

Before we discuss the problems of LNG carriers, those of natural gas itself must be discussed in comparison with the other energy resources. That is the major premise. One of the greatest merits of natural gas is that it is environmentally more sound than the other energy resources, especially as to the rate of CO_2, SO_x and NO_x emission, more precisely the emission per thermal unit, as is well known recently. Another is that it has comparatively larger reserves globally.

On the other hand, natural gas has some demerits. One of them is that its market price is often comparatively high, especially in Japan. A reason for that is ascribed to the complicated market system or mechanism, which is rather conventional at least in Japan. This is an economic or social reason. Another reason is ascribed to technical problems. Among those problems, difficulties in the transportation of natural gas are major ones, which are, in turn, related to economic problems, too, for instance, comparative costs problems.

Both economic and technical problems are closely related with each other, and the possibility and potential of natural gas should be thought from the above-mentioned background and this viewpoint. The contrivance is necessary to develop its merits and repress its demerits.

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So far, scientific or analytic and appraisal techniques for natural gas utilization and transportation have been rather separately making progress, but the scientific theory to integrate them, it seems, has not yet sufficiently been developed. Now, the development of such scientific theory is sought and the above-mentioned contrivance should be tried in this direction.

2. The cost of natural gas transportation by LNG carriers

If a nation depends on import for the domestic supply of energy to a great extent, the choice of natural gas as energy resources and how the nation import it, depend on the national policy. The national policy is affected by its cost compared with those of the other energy resources, the available ways of its transportation and, recently in addition, environmental problems. Here, all-round and synthetic economic effects must be taken into account from a large-scale and long-term viewpoint. As for natural gas, the problem of transportation is especially important consequently.

From the usual viewpoint, the cost of transportation by LNG carriers or tankers consists of cost or expenses for its liquefaction in the exporting country, freightage, insurance, storage and cost or expenses for regasification in the importing country, and, in the end, assessed by cubic or thermal volume.

Freightage is finally ascribed to the following costs and expenses. One is the construction and reparation cost of the LNG carrier and the interest to the whole investment including imputed one, divided by the cubic or thermal volume of natural gas transported during the life of the carrier, which is usually said to be 20 years. Precisely, the value of the scrap must be evaluated against the cost. Construction cost per term must precisely be distinguished from depreciation expenses. Another is the sum per volume of the cost including the fuel cost, the general and administrative expenses for navigation, of the shipping company or the gas or electric power company if it is the owner of the tanker.

The cost and expenses for liquefaction and regasification are finally ascribed to the following ones. One is also the construction and reparation cost of the plants and the interest including imputed one, divided by the volume of natural gas processed by the plants during their lifetime. Another is the sum per volume of the cost, and the general and administrative expenses for their operation. The liquefaction plant is usually run by the companies in the LNG exporting country, but that is not so essential problem, apart from the difference of the relevant technologies among the countries. The liquefaction cost is, of course, to reflect on the price of the natural gas in the importing country.

Finally the above-mentioned costs and expenses are to be aggregated, and coordinated by adding the value per volume of the loss of natural gas in transportation and regasification. The loss in liquefaction could be considered by the companies in the exporting country. The value of the coordinated, aggregated costs and expenses could be the finally assessed cost per volume of transportation by an LNG carrier. It reflects on the price of natural gas in the imported country. By the way, the price of natural gas in the imported country consists of the original price of natural gas itself in the exporting country which contains liquefaction cost, the above-mentioned transportation cost, the distribution cost in the importing country and profit, per volume unit. The problem of relevant technology is to be discussed later.

3. The comparison of NG transportation costs between carriers and pipelines

Another way of transportation of natural gas is that of natural gas or NG pipelines. The cost of transportation by pipelines is ascribed to the following ones. One is related to their construction including that of boosting and pumping equipments. If the pipeline is to be used semipermanently by continuing to repair and maintain, the cost per volume relevant to the construction will consist of the sum, during a certain term, of the everlasting interest including imputed one on the construction cost never withdrawn and everlasting reparation and maintenance expenses, divided by the volume of natural gas transported during a certain term, or per volume. Another is also the sum per volume of the general and administrative expenses for running the pipeline. The third is the land purchase cost or rent for the construction, which could be included into the construction-relevant cost. The forth is the value per volume of the loss of natural gas in the transportation.

So far, the transportation cost of natural gas has been discussed rather theoretically. One important point is in what range to think the constituent elements of the transportation cost. Actually it is difficult to find the examples of the assessment of transportation cost strict to the theoretical one, but it is necessary to compromise with the present actual state of affairs to an extent for the time being, though more theoretical assessment must be made in future. Some examples seem to be fundamentally based on that, though not so theoretically strict. Here, the comparison of transportation costs is to be made between the LNG tanker and the NG pipeline, adopting one of such concrete examples, and the following equations are to be considered and discussed on.[1]

The transportation costs, of course, vary according to the distance, whether an LNG carrier or an NG pipeline.

(1) $y = 0.078x + 1.88$　　the LNG carrier

(2) $y = 0.45x + 0.54$　　the low cost NG pipeline

(3) $y = 0.81x + 0.95$　　the high cost NG pipeline

y : \$ per Mbtu (million British thermal unit)　　x : thousand kilometers

The constant in the right side means the largeness of fixed cost. The fixed cost of the LNG carrier is larger than those of the pipelines. That suggests that the equipments at the ends or terminals in the LNG carrier transportation route such as the liquefaction and regasification plants cost more money relatively. In contrast, the equipments at the ends of the pipeline transportation route cost less money relatively. In the carrier transportation, of course, the longer the distance is, the less the rate of the equipment load per distance unit gets.

The coefficient of x means the rate of the cost increase according to the increase in distance. The coefficient of the NG pipeline is larger than that of the LNG carrier. That suggests that the transportation cost of the pipeline increases more abruptly according as the distance gets longer. In contrast, that of the carrier increases not so abruptly. In other words, the marginal cost of the pipeline is always larger than that of the carrier. So, the carrier transportation is more advantageous if the distance is sufficiently long.

1) Those equations have been made from the data in Fig. 1-4, ② of "The Symposium on Natural Gas Pipelines", the Japan Institute of Energy, 1998, p. 24, whose original seems to be in "Natural Gas Transportation", IEA/OECD, 1994 and Jensen Associates, Inc.

4. The system of natural gas transportation in the Northeast Asia and Japan

The advantage of the long-distance transportation by the LNG carrier is a reason that Japan has been importing natural gas from the Southeast Asia, the Middle East, Australia and Alaska, not from Russia. The natural gas exportable areas in Russia and Kazakhstan are far from Japan and there exist lands or terrestrial parts between them and Japan. Consequently, Japan chooses and adopts the natural gas exporting areas from which the LNG carrier transportation is available, if any is far from Japan. Only Sakhalin is near to Japan as a natural gas exportable area in Russia and there exists no land between it and Japan. So, Japan has been interested in the natural gas in Sakhalin, and the plan of constructing a pipeline between them, as the distance is short from Japan.

Thinking about the development of the Northeast Asia in future, it is necessary for Japan to cooperate economically and technologically in the development of natural resources including natural gas. That is closely related to Japanese use of Russian natural gas, which brings about Japanese intention to cooperate in its development. Here, the formation of the route for natural gas transportation is necessary, so that Japan may use it. The problem is which is better, the transportation by a carrier or that by a pipeline. The route from any NG drilling part of the Asian Continent to any point including a port on the coast of the Sea of Japan or the Yellow Sea in Russia, China or the Korean Peninsula could not be other than the pipeline. The final problem is between the points there and Japan.

Here, the equations (1), (2) and (3) mentioned above are to be considered again. It is to be necessary to elucidate the diverging point of advantages and disadvantages. The diverging point is shown by the intersecting point between any two equations. The coordinate of the diverging point between the equations, (1) and (2) is (3.6, 2.16), which means that, if the distance is shorter than 3,600 kilometers, the low cost pipeline is more advantageous than the carrier, and that, if the distance is longer than 3,600 kilometers, the carrier is more advantageous than the low cost pipeline. Likewise, the coordinate of the diverging point between the equations, (1) and (3) means that, if the distance is shorter than 1,270 kilometers, even the high cost pipeline is advantageous than the carrier, and if the distance is longer than 1,270 kilometers, the carrier is advantageous than the high cost pipeline.

The distance between Vladivostok in Russia and Niigata in Japan, for instance, is 850 kilometers, that between Pusan in Korea and Fukuoka in Japan is 240 kilometers, and that between Talien or Tsingtao and Fukuoka is 1,000 kilometers. Those distances are all within the reach to the diverging point, judging from which it seems that the pipeline is more advantageous there, especially between Korea and Japan.

It is necessary, however, to consider this problem from another point of view. Indeed the distance itself between Korea and Japan is short, but the natural gas transported, for instance, to Fukuoka by the pipeline must again be transported to Osaka, Nagoya, Tokyo, etc. and Fukuoka could not be the terminal from economical viewpoint, as the investment in the construction of subsea pipeline might be not so small. The distance between Fukuoka and Tokyo is 1,000 kilometers. It is more advantageous to cover the distance by carrier transportation or navigation, as it takes much money and much time to secure land for pipeline construction in Japan. If so, it could be said that it is better to cover at once the total distance among Korean coastal points, Tsintao, Vladivastok, Fukuoka and Tokyo, and so forth, by carrier transportation or navigation system in a circular tour, for the time being, which could make the total distance longer enough across the above-mentioned diverging point, if systematically well connected.

From the long-term viewpoint, however, a pipeline system might be preferable there. That depends on the future development of the technical, economical and geopolitical conditions. It is necessary to combine and unite the long-term projects and the short-term projects from economically and econometrically rational viewpoint, basically to optimize natural gas synthetic transportation systems and subsystems from the sustainable viewpoint of the maximization of the long-term social utility in the social welfare function.

On the other hand, liquefied natural gas is convenient for storage, and its new combined usages have been found and developed as if they were two-bird-one-stone solutions. As for them, there are numerated the production of liquefied nitrogen, oxygen, argon and carbon dioxide including dry ice, the refrigeration in the super-low temperature warehouse, the power recovery from LNG or power generation combined with regasification, etc. as outgrowths with LNG regasification. Moreover, the relevant technology of the carrier, regasification and liquefaction plants is now rapidly making progress, which is expected to contribute to reducing substantially LNG transportation costs in future. The consideration is also necessary about such a state of affairs.

Discussions are to be made on the technology in Section 5.

[Supplementary discussions]

The relation between the transportation costs and the distance has been treated as linear so far. Actually, the state of affairs is rather complicated about the relation. Here, the model is to be set up in more extended form according to the actual state of affairs and carrier transportation system in a circular tour just mentioned above.

First, the distance is assumed between a port of the Asian continent and a terminal point of Japan, for instance, Tokyo. The distance is to be covered by the navigation of an LNG carrier. The demand of LNG in Tokyo is assumed to be fixed. The LNG carrier could stop over at any port on the way and supply LNG there. The object here is to maximize the difference or value between the nationwide total gains and the nationwide total transportation costs. Here, the largeness of the LNG carrier is determined according to the volume of LNG supplied on the way. Its construction costs or charter expenses are, of course, included into the transportation costs.

Here, a functional and calculus of variations are applied to the model.

$$u = \int_{t_0}^{t_1} p(t, x, \frac{dx}{dt})\, dt \quad ; \quad p(t, x, \frac{dx}{dt}) = r(t, x, \frac{dx}{dt}) - c(t, x, \frac{dx}{dt})$$

where u stands for the nationwide total difference or net gains, p for the net gains of the points on the way and the terminal which are assumed to be continuous, t for the distance from the port of the Asian continent, x for the quantity of LNG supplied, r for gross gains or revenue which, of course, includes the gains from power recovery from LNG, etc. as outgrowths, and c for transportation costs.

Euler's equation is expressed by

$$\frac{\partial p}{\partial x} = \frac{d}{dt}(\frac{\partial p}{\partial x'}) \quad ; \quad x' = \frac{dx}{dt}$$

and the function is determined which maximizes u.

5. The technology of the LNG carrier and regasification and liquefaction plants

(1) LNG carrier

A technically important point of the design of the LNG carrier or tanker is the protection of, directly, its tank filled with liquefied natural gas and, indirectly, its hull itself against ultra-low temperature (−162°C) and sloshing. As for ultra-low temperature, there are mainly two problems. One is that the material must be proof against the ultra-low temperature itself, and another is that the material must be proof against the physical distortion by the temperature or free of the distortion. The development of such material is expected. The leakage of liquefied natural gas is very dangerous. It sometimes occurs through the hole in the tank caused by the distortion.

There is now the international safety guard or standard set up by the IMO (International Maritime Organization). So far, the technology of the LNG carrier has been developed through the accumulation of technical experiences ranging over near to half a century. There are finally four systems for the LNG tank or containment technology. First, the technology is divided into two main classes. One is the self-supporting system, and another is the membrane system. Historically, the former system precedes the latter. These two systems are further classified into two types each. Each type or system has its own merits. Moreover, as for self-supporting system, there are two types. One is spherical containment system. Another is cubic shape containment system.

The self-support spherical containment or tank was developed by Moss, Norway.[2] The tank, which is made from aluminum alloy and covered by cool-keeping plastic, is designed to be welded to the cylindrical skirt, which is made from aluminum and steel or stainless steel. The tank shrinkage by ultra-low temperature of liquefied natural gas is absorbed by the distortion of the skirt. The spherical tank is said to be strong against internal pressure but weak against external pressure, so the special device controls and represses the difference between internal and external pressure.

The SPB[3] self-support cubic shape system has been developed by IHI (Ishikawajima-Harima Heavy Industries Co. LTD), Japan. The tank is covered also by plastic and supported by the ship bottom, with follow rests or traveling stays that are designed to rest the traveling but not to resist the distortion of the tank, adopting block guide system.

TGZ membrane containment system[4] was developed by Technigaz, France. The tank is made of the stainless steel membrane with waffle-like elastic wrinkles that absorb the distortion of the tank. It is being tried to change the cool-keeping material from balsa to strengthened polyurethane and to change the secondary protective wall from the plywood to the plastic sheet strengthened with sandwich-structured aluminum foil and glass fiber. There is installed the device to control differential pressure between the inside and outside of the tank and to repress a vacuum formed.

GT membrane containment system[5] was developed by Gaz-Transport, France. The tank is made of very thin invar membrane (0.7 mm thick). Invar is steel with 36% nickel and exhibits the least coefficient of thermal expansion, precisely the coefficient less than stainless steel by 1/10. Here, the development of welding technology is one of the most important key for the development of invar membrane method. The cool-keeping is made by the plywood box filled with perlite, which also supports the force from the tank. The plywood box conveys the force to the hull. So, the hull supports the force from the tank finally. The whole structure is so formed that the boxes connected with one another surround the tank as if a container as a whole. There is also installed the device to repress the differential pressure between the inside and outside of the tank and repress a vacuum formed.

Afterwards, GT (Gaz-Transport) and a ship building department of TGZ (Technigaz) have merged into GTT (Gaz-Transport & Technigaz). The GTT, inheriting the technology of GT system, is developing it further. The other ship builders are developing their technology, too, in market competition. The development of the technology, of course, will reduce the cost of natural gas transportation. As for the technology, there are numerated thinning of the tank, economic enlargement of the ship size, economic reduction of LNG carrier construction cost itself, reduction of the maintenance cost of the carrier, extension of the life of the carrier, accident prevention, reduction of environmental pollution and disruption, having long-term economic and technological viewpoint of LNG carrier design, deliberate simulation from the viewpoint of all-round conditions, etc.

(2) LNG regasification plant and the relevant infrastructure[6]

For the liquefied natural gas transported by an LNG carrier, the relevant infrastructures on the port such as the berth, the lot for storage tank, etc. come to be necessary. Those are closely related to the administration. There are to be set up the storage facilities, the unloading arm and pipes which bridge between it and the LNG carrier, and BOG (Boil Off Gas) compressor. The stored LNG is to be transported to the LNG regasification plant according to the necessity. By the way, the cost for the construction of the infrastructure and the relevant interest should be numerated as a part of the transportation cost in social or national assessment.

Stainless steel, aluminum alloy and steel with nickel are usually chosen as the inside surface material of the LNG storage tank. The choice is conditioned by welding techniques to an extent. Their technical progress will expand the range of choice of low temperature-fast steels or other metals and enable the enlargement of the tank. The technology of underground LNG storage tank is being developed in such countries as Japan, where land prices are high.

As for regasification, there are mainly two kinds of devices. One is ORV (Open-rack LNG vaporizer), which gasifies LNG through thermal exchange with seawater, and so, whose running cost is comparatively low. On the contrary, the equipment cost is comparatively high, for instance, using many LNG pipes and manifolds. Recently, however, the technology was developed in Japan, to use invar, whose coefficient of thermal expansion is very little, as excellent material for LNG pipes and manifolds, which could make the material cost lower by 20%, compared with stainless steel used so far. Another device is SMV (Submerged LNG Vaporizer) which uses gasified LNG as thermal source, which results in the comparatively high running cost and comparatively low equipment cost. The two systems should be properly used according to the cases, for instance, ORV as baseload use and SMV as peak-hour or emergency use.

(3) NG liquefaction and the relevant infrastructure[7)]

The principal ingredient of natural gas (NG) is methane (CH_4). The removal of acid gases from natural gas is an important problem at the first stage of the liquefaction train. The acid gases are usually CO_2, H_2S, etc, which could be the material for chemical industries, for instance, such as liquefied CO_2, H_2SO_4, etc., though, actually, CO_2 is at present being discharged into the air. Thus, acid gases are removed from natural gas first, and moreover, H_2O and Hg are removed.

Next, the natural gas is introduced to the liquefaction equipment. There, heavy hydrocarbons are removed from the natural gas and afterwards introduced to distillatory equipment. The ethane and propane brought about in the distillation process are collected and added to refrigerants for the liquefaction, and the light hydrocarbons are recycled and introduced to the liquefaction equipment as a part of material for liquefied natural gas (LNG). Some kind of liquefaction process systems are provided by some licensers.

One is the CASCADE process system provided by Technip, the licenser. The process uses three refrigerants, that is, propane, ethane and finally methane separately at three stages through different compressors and pipes according to the physical nature of each gas, which makes complicate the machinery and devices and so requires relatively high capital cost, though thermodynamic efficiency is high.

In comparison, the 3C-MCR process system provided by Air Products & Chemicals Inc., for example, uses mixture of refrigerants, that is, nitrogen, methane, ethane and propane, which means smaller machinery and so relatively low capital cost, but thermodynamic efficiency is relatively not so high. Recently, there appeared improved multistage MRC, which has higher thermodynamic efficiency than the types so far.

So far, two different but important examples have been discussed for comparison. The important thing is finally to reduce the aggregated total cost and more directly reduce the average cost technically and by the appropriate selection and adoption among the existing liquefaction process systems, and economically or finally to invest up to the optimal point that the marginal cost is to be equal to the marginal revenue. From the viewpoint of economics and precisely, the comparative cost, in comparison among the different process systems, should be considered in the assumptive condition of equality of marginal cost and marginal revenue. That is fundamentally the same also in the cases of (1) and (2).

The CASCADE, of which the power consumption is small and the capital cost is high, is fitted to larger-sized trains or plants. Its economical efficiency could be strengthened by pre-cooled refrigerant cycle, whose type is usually the mixed-refrigerant one in the case of the CASCADE. In comparison, MCR is fitted to rather small or middle-sized trains or plants.

By the way, decrease in the cost of liquefaction leads to decrease of the price of natural gas in the importing country in the end, though liquefaction itself is made in the exporting country.

2) Japan Institute of energy, "comprehensible Natural Gas—All about New Energy Resources—", Korona-sha, 1999, p. 73.
3) ibid., p. 74.
4) ibid., p.p. 71-72.
5) ibid., p. 70-71.
6) ibid., p. 89 et seqq.
7) ibid., p. 55 et seqq.

6. Economic effects of LNG carrier in the Northeast Asian Economic Region

So far, the direct discussions have been made on the economic and technical side of the LNG carrier. Here, the consideration is to be made from another perspective, that is, from the larger-scale viewpoint. The economic political effects should be appraised through large-scaled synthetic feasibility studies.

First, the construction of the NG pipeline system seems not to have more effect of inducing new industries along its route, if compared with the LNG carrier system. It is probable that the pipeline passes by straightly, at least, could pass by without relation to the areas on the way. Of course, it could supply natural gas on the way, but might not be so much expected to bring necessarily such an economic effect as inducing new industries and having an economic positive repercussion on the way. That means that demand precedes supply economically, and the distribution of natural gas on the way depends on its industrial demand, namely, the appearance or creation of new industries. Of course, the supply itself could be an incentive to that creation to an extent, but, it seems, could not be a decisive factor for that, of itself.

On the contrary, the LNG carrier transportation system seems to have more effect of inducing new industries along its route. In other words, new investment could be induced on the way of carrier transportation. Concretely speaking, a carrier loaded with LNG (liquefied natural gas) leaving, for instance, a port in China or the Tumen River triangle zone is to cross the Sea of Japan and to reach a Japanese port on the coast of the Sea of Japan. The natural gas transported there is further to be transported to Tokyo and Osaka. In the Tumen River triangle zone and in the zones around the ports on the coast of the Sea of Japan, new industries could be induced, the natural gas is added value there and the associated infrastructures are formed around there. Those economic effects should not be neglected.

More concretely speaking, liquefaction of natural gas is necessary for LNG carrier transportation. The construction of a liquefaction plant needs a huge amount of investment, which induces associated heavy industries in the exporting country through the construction and ex post facto maintenance and reparation. The regasification of LNG is necessary in the importing country, for instance, Japan. Regasification could bring about, at the same time, power generation combined with regasification, production of liquid nitrogen, oxygen, argon and carbon dioxide including dry ice, and refrigeration in the ultra-low temperature warehouse, as is mentioned earlier, which could form a new industrial zone around the ports on the coast of the Sea of Japan. If so, the liquefaction in the exporting country is to perform a part of, for example, combined power generation, liquid nitrogen production, etc. which leads to regional cooperation and mutual prosperity in the Northeast Asia, from the large-scale viewpoint. From the long-term viewpoint, however, a considerable part of LNG carrier system might be replaced by NG pipeline system according to the changes of technological, economic, political, institutional and legal state of affairs. From that viewpoint, the two systems must optimally complete each other, and the balance between them should be thought elastically in time series and at long-term economic efficiency.

As for finance, there are private one and governmental one. Private investment is, of course, conditioned by how profitable the object of investment is. First, the investment in natural gas must be more profitable than the ones in the other energy resources and that must be clear to the investors, and the government must create the conditions for that. Let's discuss mainly according to the cases in Japan. It is necessary to reform the conventional distribution structure, to exclude the administrative prices, to reform the commercial usage or trade custom and to make the market freer and more competitive, in order to lower the domestic price of natural gas. From the larger-scale viewpoint, it is also necessary to reduce the import cost, for instance, through adoption of swap trades method among several countries.

Next, if the carrier transportation system is to be adopted for the expanded demand of natural gas, such local industrial zones are apt to be induced around the ports, as is mentioned earlier. Moreover, the construction of the infrastructures for the ports and the industrial zones is also to be induced. That is the same, for instance, with the Tumen River triangle zone. It will give opportunities for private investment.

Japanese economy has already reached a maturity stage and the demand-creating Keynesian policy is not so effective as in the past. A new element is sought to induce new investment and to create new social demand. The increase in import of natural gas and the formation of the carrier transportation system for it home and in the near foreign countries will contribute to that purpose, through repercussion effects. Those economic effects should be econometrically analyzed.

From the perspective of the Northeast Asian economic region, the economic development of any part of the region will contribute to that of each other. This recognition will urge the government's investment or finance. The government could assist the domestic industries that invest abroad and could give a loan to the foreign countries of the region. The happy economic policy will create new social demand and new investment also in any part of the whole Northeast Asian region.

Of course, the pipeline system has its own merit. The policy is necessary to make the most of the merits of both pipeline and carrier transportation systems. Roughly speaking, pipelines are thought to be effective among China, Mongolia, the Democratic People's Republic of Korea, the Republic of Korea and the Far East of Russia, and the carrier transportation system is thought to be more effective between them and Japan for the time being, except for between Sakhalin and Japan. It is, however, necessary at the same time to continue to discuss the possibility of subsea pipelines between them and Japan, too, according to the expected development of technology and the expected change of the economic conditions. Finally, the large-scale and long-term project is necessary of the Northeast Asian economic region. For that, it is necessary to further the economical and econometric analysis and research and to make the accurate input-output tables of the whole Northeast Asian economic region.

From the large-scale economic geopolitical viewpoint, for instance, Japan could assist the other countries of the region through its technology and finance. In the middle latitude the air moves from the east to the west in general. Japan is located to the east of the Asian continent. Winter seasonal winds blow from the north or northwest around there, in addition. If the countries in the Northeast Asian economic region change coal or oil for natural gas as energy resources, the threat of acid rain in Japan will be reduced as much. Japan could finance that as far as gains are greater than the cost for finance. Consequently, the natural gas pipelines from Russia in China are to be extended, which, in turn, would provide gains to the whole Japanese society and provide facility also to Japanese LNG carriers transportation system.

7. Financial problems

First, the state of affairs in Japan is to be considered. There are nine government-affiliated financial institutions in Japan which are related to the long-term national economic policy. Among them, the institution relevant to the case of the construction or purchase of an LNG carrier is to be the Development Bank of Japan. The constructed LNG carrier is sometimes owned by a single corporation and sometimes owned by plural corporations jointly. There is, however, no national special finance for them, whether the applicant is an LNG shipping company, a gas supplier or an electric power company. The financing conditions for them are fundamentally the same as in the other financing cases in this institution. Next, the state of affairs in the case of the Development Bank of Japan is to be discussed more concretely and more detailedly.

First, one of the above-mentioned matters, that is, the construction or purchase of an LNG carrier can be the object of financing or loan by the Development Bank of Japan. The condition or premise for financing is the existence of the contract for purchase of the LNG carrier to be constructed. The financing rate is 40～60% of the contract amount. The amount of finance is not limited, and is decided case by case. The loan term is not limited, either, but the contract of 15 years is common in the case of those matters in Japan. In this case the interest has been fixed and usually 2.25% recently. The loan amount is left unredeemed for three years and afterwards paid off in installments usually spread over 12 years, that is, the loan term is usually 15 years as a whole.

Most of Japanese LNG buying corporations have usually been making contracts for about 20 years with foreign LNG selling corporations. Both of this contract term and the above-mentioned loan term, which is a little shorter than the former, are often said to be originally based on the 20 years life term that has usually been thought to be effective so far, of the common LNG carrier, and the term is also thought to be appropriate for stable LNG supply. By the way, the life of the LNG carrier is getting longer and longer according to the development of the technology of LNG carrier construction. On the other hand, there is appearing the tendency that the long-term contract is partly to be replaced with the shorter-term one as to Japan.

An example of the percentages per item of the LNG carrier costs and expenses is shown bellow.[8)]

1)	Liquefaction plant (nominal processing capacity : 1,000 MMcf/d)	(22%)
	details direct construction cost	〈17%〉
	spare stock, design cost, loyalty	〈 2%〉
	management expenses, interest	〈 3%〉
2)	Tanker (transportation distance : 6,600 miles)	(66%)
3)	Regasification plant (nominal processing capacity)	(12%)

The percentage of liquefaction plant construction cost is rather large among the LNG transportation costs and expenses.

Most Japanese natural gas buying corporations directly buy liquefied natural gas (LNG), and do not concern themselves in natural gas liquefaction itself. Natural gas liquefaction plants are constructed by the major international oil or NG companies, the native or national capital corporations or the joint enterprises between them. In the case of the native or national corporations especially in developing countries, the fund for the construction sometimes comes to be in short supply, and there are brought about finance problems. Japan as a developed country is backward in financial help to the developing countries for NG liquefaction plant construction.

A reason for that is the large dependence of Japan on oil or petroleum so far. Now, the Japanese government is under pressure to change its policy also from the environmental viewpoint. Of course, natural gas is environmentally more sound than petroleum. The government can not but turn its attention to natural gas more earnestly than before, and the circumstances will become favorable for the investment in natural gas development including the NG liquefaction plant construction, though there are no benefits for either investment or finance for the investment at present. Moreover, the Japanese government could come to give financial help directly to the developing countries, if it is to recognize and understand that the financial help is consequently serve the best interest of Japan. The concept of development of the Northeast Asian economic region will contribute to enhancing that tendency. On the other hand, the International Bank for Reconstruction and Development (IBRD) or the International Finance Corporation (IFC) could finance the corporations in the developing countries for NG liquefaction construction and finance the governments there for the relevant infrastructure construction for NG liquefaction plants and shipping points for LNG. As for the financing problems all-round consideration is necessary.

8) op. cit., "Comprehensible Natural Gas—All About New Energy Resources—", the Japan Institute of Energy, 1999, p. 53.

The references

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